

# Major Concepts in Physics

## Lecture 13.

Prof Simon Catterall

Office 309 Physics, x 5978

[smc@physics.syr.edu](mailto:smc@physics.syr.edu)

<http://physics/courses/PHY102.08Spring>

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# Plan for today - review

- Topics
- Practice exam

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# Announcements

- Exam 2 – Wednesday March 5 in class
  - Online: exam sample plus solutions, homework2 solutions, quiz 2 solutions
  - Material: everything from lecture 8-12 inclusive (thermal radiation, line spectra, color mixing, ray approx, reflection, refraction, mirrors, lenses, polarization)
  - Similar in format/style/grading to exam 1
  - Review session in class on Monday March 3

# Thermal radiation etc

- Be able to define blackbody:

Idealized object that absorbs/emits most efficiently any EM wave

- Stefan's law: amount of energy emitted/absorbed every second by blackbody

$$E = \sigma AT^4 - T \text{ in Kelvins !! } A \text{ in m}^2$$

- Wien's law: peak of intensity distribution occurs at wavelength  $\lambda T = 2.898 \times 10^{-3}$

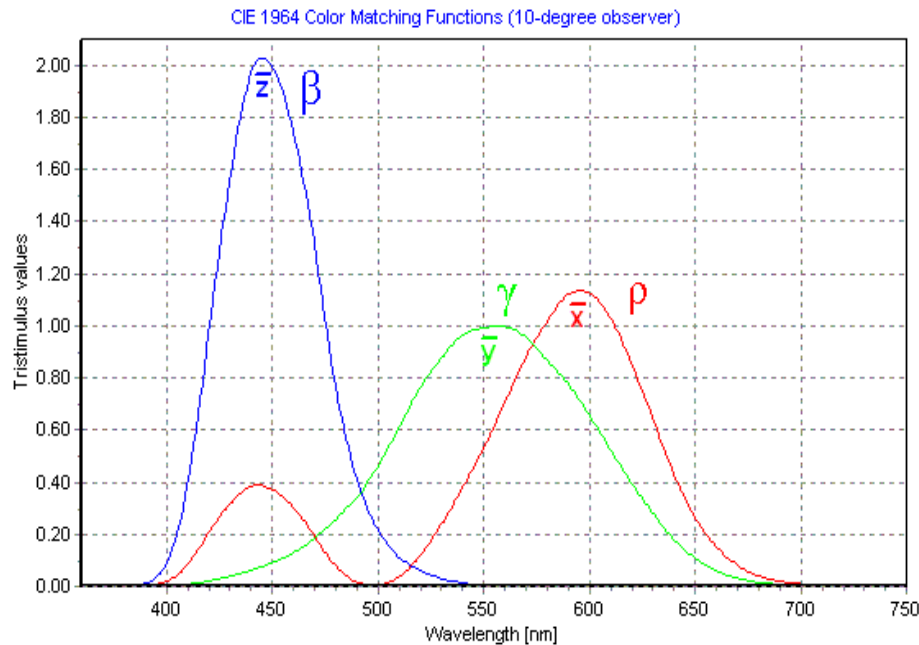
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# Line spectra

- Blackbody spectrum applies to dense matter comprising many types of atoms.
- Single atoms give rise to **discrete line spectra** which give unique fingerprint of atom in question.

# Color mixing

- Eyes sensitive to 3 colors: red, green and blue – primary colors.



**RGB cone sensitivity to light**

# Adding color

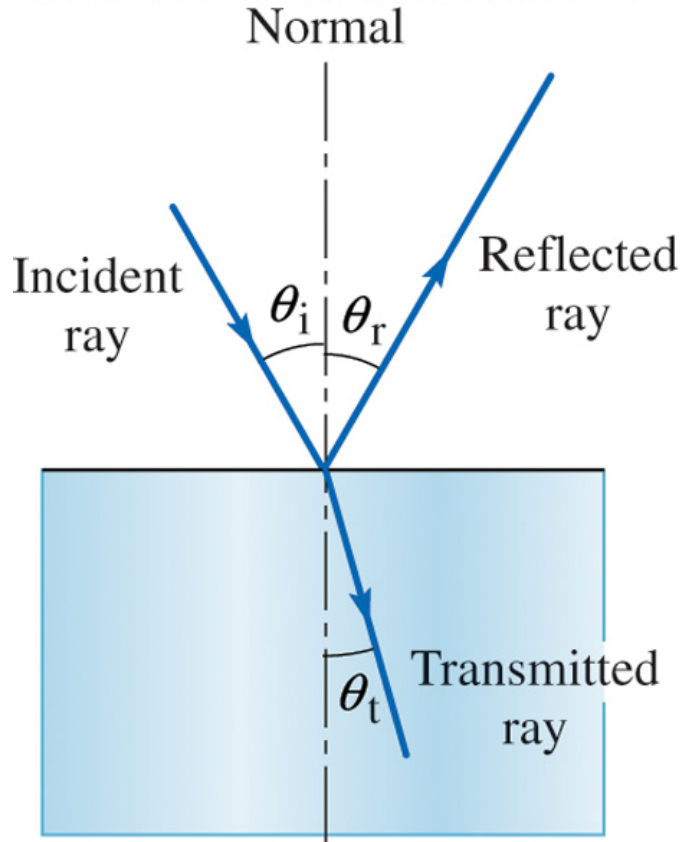
- Two ways to perceive yellow light
  1. Light of wavelength 580 nm hits retina
  2. Equal amounts of red and green light hit retina
- Know how to add primaries
$$R+G=Y, R+B=M, G+B=C, R+G+B=W$$
- Know how a color filter works – by allowing through only certain colors
- Combine filters: eg.  $Y(\text{filter})+M(\text{filter})=?$

# Rays ...

- When  $\lambda \ll$  sizes can ignore diffraction effects and treat light as following straight line paths
- Replace wavefront – by ray showing direction of travel.
- Not completely simple: waves can still be reflected and bent (refracted) by media.

# Reflection and refraction

- Law of reflection: angle incidence=angle of refraction (measured from **normal**)
- When light/wave passes from one medium to another its speed (and hence wavelength) changes –  $c \rightarrow c/n$ ,  $\lambda \rightarrow \lambda/n$
- $n$  depends on material. Also depends in general on wavelength – **dispersion** of prism
- Snell's law ...



## Snell's Law

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where the subscripts refer to the two different media. The angles are measured from the normal.

When going from high  $n$  to low  $n$ , the ray will bend away from the normal.

# Total Internal Reflection

For angles of incidence greater than the critical angle there is NO transmitted ray. Need  $n_2 < n_1$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1 \sin\theta_c = n_2 \sin 90^\circ = n_2$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

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# Mirrors/lenses/geometrical optics

- Use basic laws to understand behavior of simple optical systems
- Know how to draw a **ray diagram** showing how to use 2 primary rays to locate image
- Understand focal point/focal length for mirrors and lenses – rays parallel to symmetry axis pass (maybe after back tracing) through one of the focal points.
- **Virtual and real images**

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# Ray diagrams

- Draw in ray parallel to axis.
- For mirrors draw in ray which hits center of mirror – easy to draw reflected ray
- For lenses draw in ray which goes through center – easy to draw.
- Where rays cross – image is. Sometimes need to trace back physical rays

# Mirror/lens equations

- $1/f = 1/p + 1/q$   
f=focal length (positive for converging lens/mirror, negative for diverging)  
p=object distance (always positive)  
q=image distance (negative q means virtual image)
- $m = \text{image height}/\text{object height} = -q/p$   
negative m means **inverted**

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# Polarization

- Light has 2 possible transverse directions for E-field – polarizations – revealed by polarizing filters ...
- Sunlight contains equal amounts of each. Reflected light is partially polarized
- When angle of incidence equals Brewster angle  $\tan(\theta_B) = n_t/n_i$  reflected light is completely polarized in direction **parallel to surface**

Position: # (your seat #).....

Your Name: Last, First.....

Name of Workshop Instructor: Last, First.....

Total points: 42

$c=3 \times 10^8$  m/s (the speed of light)

$$f = \frac{1}{T} \quad (\text{SI unit Hz} = \text{s}^{-1})$$

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(5-8)

$$v = \frac{\lambda}{T} = f\lambda$$

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(11-6)

Wien:  $\lambda T = 2.898 \times 10^{-3}$  Km

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**Stefan's law of radiation (blackbody):**  
$$\mathcal{P} = \sigma AT^4$$
 (14-15)

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$$\sigma = 5.670 \times 10^{-8} \text{ W}/(\text{m}^2 \cdot \text{K}^4)$$

(14-16)

reflection:

$v=c/n, \lambda=\lambda/n, n$  refractive index

$$\theta_i = \theta_r$$

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**Snell's Law**  
$$n_i \sin \theta_i = n_t \sin \theta_t$$
 (23-4)

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refraction

**Critical angle:**  
$$\theta_c = \sin^{-1} \frac{n_t}{n_i}$$
 (23-5a)

Total internal reflection

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**Mirror equation:**  
$$\frac{1}{P} + \frac{1}{q} = \frac{1}{f}$$
 (23-10)

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**Magnification equation:**  
$$m = \frac{h'}{h} = -\frac{q}{p}$$
 (23-9)

**Brewster's angle:**  
$$\theta_B = \tan^{-1} \frac{n_t}{n_i}$$
 (23-6)

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**Q1.(8pts)** Estimate the energy radiated from a person whose skin is at temperature of 32 C. Assume the total surface area of the person is 2.0 m<sup>2</sup>. At what wavelength is most energy emitted ? What is name given to this type of radiation ? If the room where the person is sitting is at 20 C what is the net energy which must be supplied by the body to maintain this temperature.

**Q2.(3pts)** Calculate the speed of EM radiation in a material whose refractive index is 1.5. If the radiation has a frequency of  $1 \times 10^{14}$  Hz what is the wavelength in the medium ?

**Q3. (2 pts)** A white light source is viewed through a combination of yellow and magenta filters. What color is perceived ? Explain your answer

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**Q4. (3 pts)** Explain what is meant by a light ray. What criterion must be satisfied if the propagation of a light wave is to be successfully described in terms of rays ?

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**Q5. a) (2pts)** What is the angle of refraction when light passes from air into diamond at an angle of incidence of  $60^\circ$  (assume the refractive index of diamond is 2.42).

**b) (2pts)** A beam of light passing is observed to be refracted on passing from water to air. The angle of incidence is  $30^\circ$  and the angle of the refracted beam is  $41.7^\circ$ . What is the refractive index of water ?

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**Q6.(5 pts)** An object is placed at a distance of 40 cm from the center of a thin converging lens. The focal length of the lens is 20 cm. What is the distance of the image from the lens. Is it real or virtual ? What is the ratio of the image size to object size ?

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**Q7. (7pts)** An object of height 3cm is placed at distance of 10 cm from a converging mirror whose focal length is 20 cm.

Sketch a ray diagram showing the location of the image. Is the image real or virtual, upright or inverted ? Use the mirror/lens equations to find the location of the image and the size of the image.

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**Q8. (3pts)** Calculate the critical angle for total internal reflection for a diamond under water (the refractive indices for water and diamond are 1.33 and 2.42 respectively)

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**Q9. (3pts)** Sunlight reflected off a still lake is observed to be perfectly polarized if the angle of incidence is precisely  $53.1^\circ$ . Calculate the refractive index of water. In what direction is the reflected light polarized ?

**Q10. (2pts)** What is the temperature of a blackbody if the peak of the blackbody spectrum corresponds to a wavelength of  $1\text{cm}$  ?